National Aeronautics and
Space Administration

Langley Research Center
Hampton, VA 23681-0001
M/S 300

Geographic Information Systems Team

December 21, 2010

LaRC prototype tide measurement station

Summary

The LaRC GIS Team installed a prototype water level monitoring system on Brick Kiln creek on Langley Research Center property. The purpose of this system is to monitor water level fluctuations to support local tide analysis. The system consists of a pressure sensor (calibrated to read water depth) and a battery-powered datalogger which records data to internal, non-volatile memory. Collected data is uploaded to a PDA or laptop over an on-demand Bluetooth RF connection. Initial data collected over a week correlates well with data from the same period for Sewell's Point (downloaded from NOAA).

Test results:

Initial data from the system is shown in Figure 1. This plot shows the data from the LaRC system in blue and the data from Sewell's Point in red, taken over a week's time. Both datasets have been converted to NAVD88 (North American Vertical Datum of 1988) feet. Sewell's Point data was converted using the current published value for MLLW of -0.501m. LaRC data was converted using locally surveyed sensor height.

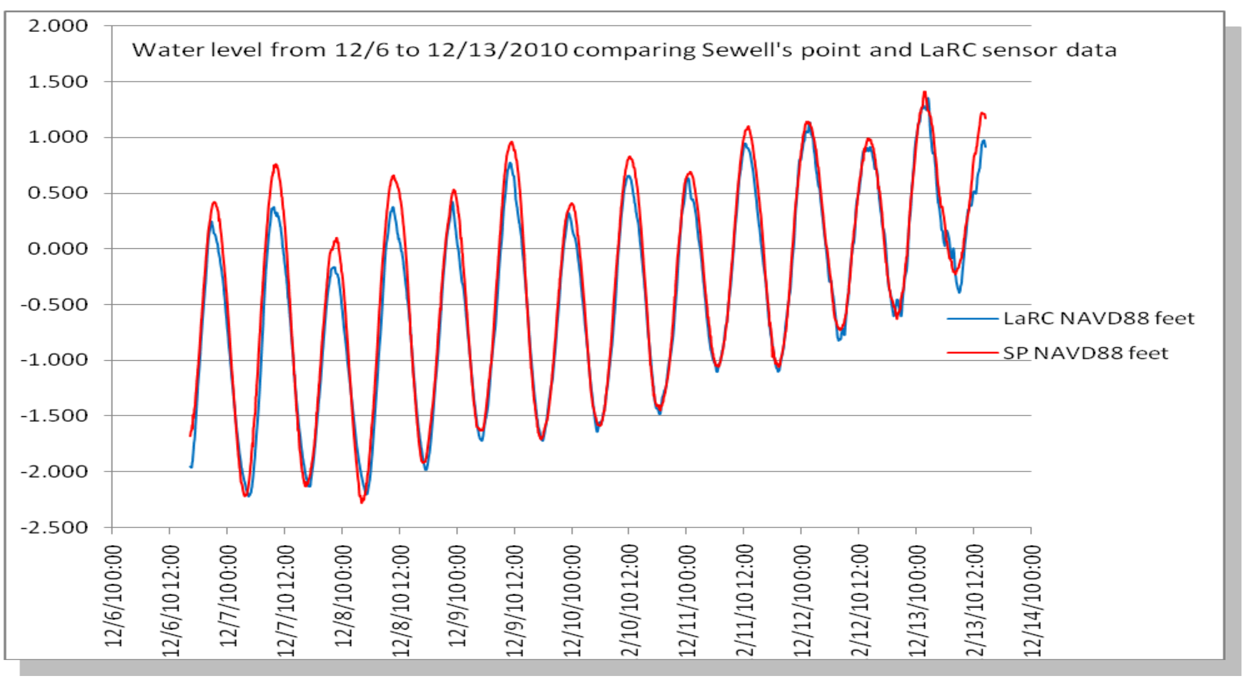


Figure 1

During this particular time span, the local area experienced significant weather changes, including both low and high pressure fronts moving through, bringing wind and precipitation. Many factors can contribute to instantaneous water level and tidal excursion at a particular point, so there is no reason to expect the curves to overlap exactly. However, the general tracking of the two datasets is close enough to provide confidence in the installation and calibration of the LaRC system.

A visual measurement standard was installed adjacent to this prototype to verify that the system readings accurately depict the water level at the sensor. This consists of a PVC pipe marked at 1” and 1’ intervals and located as part of the survey effort. The standard was observed at both high and low tide events, and the reading compared to the data from the sensor (both corrected to NAVD88 feet). The readings correlated with the sensor data within an average of 0.24” or ~6mm. Considering the difficulty of reading the standard accurately in the face of wind-driven surface fluctuations, this correlation is better than expected.

Installation

The station is located approximately 220 yards north of the ALDF (Aircraft Landing Dynamics Facility) track arresting gear assembly. It is located behind a construction debris remediation landfill, behind a locked gate. (Photo 1)

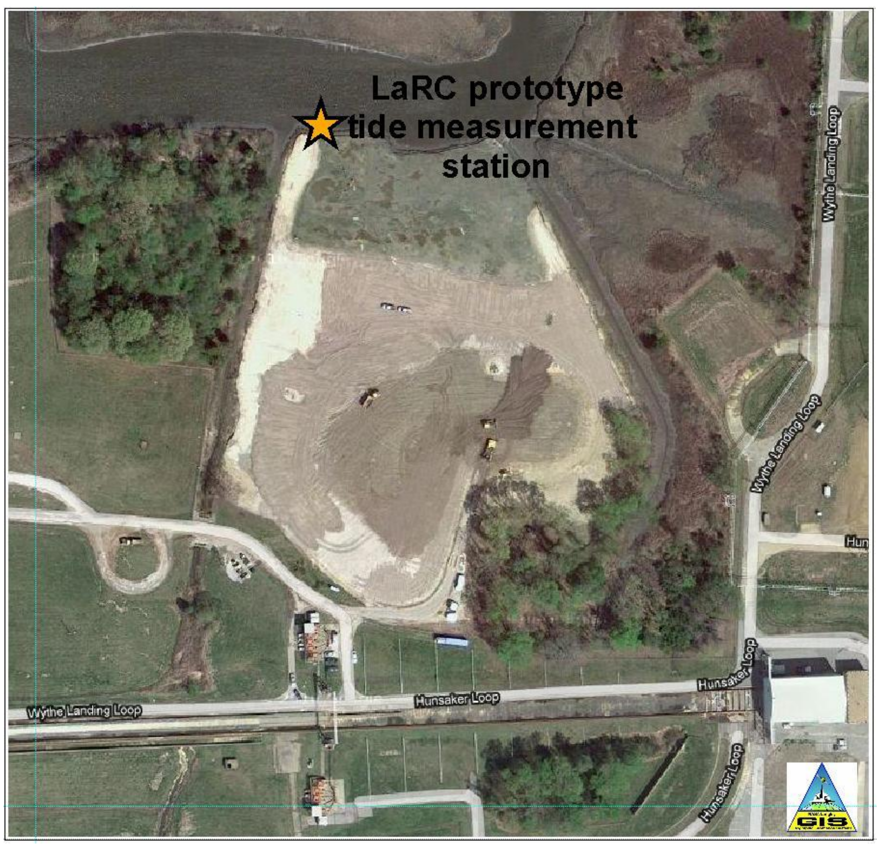


Photo 1

The sensor is installed in a special housing designed to allow free intrusion and flow of water, while protecting the sensor from animals, mud and debris.

This housing is attached to the end of a 2” PVC conduit extending into the creek approximately 18 feet from shore. Photo 2 shows the underside of this housing.

Photo 2

It is shielded from the top to prevent sediment from falling into the holes and clogging the sensor. The sensor is positioned below the lowest anticipated water level (Specifically, approximately 10” below predicted Mean Lower Low Water (MLLW)), and calibrated to read in feet of water above the sensor. The sensor is designed to register between zero and 15 feet of water depth, which will cover any anticipated situation, including severe storms, hurricanes and other flooding events.

The datalogger is installed in a dry enclosure at the top of the conduit, located about 8.5 feet above ground, attached to a central support (Photo 3). This support is a 4x4 pressure treated post, 12’ long, driven into the ground approximately 3.5’. This was chosen to provide support to the dry housing for the electronics (Datalogger and Bluetooth module) far above expected flood waters.

Photo 3

Data

Data is collected at 6 minute intervals, matching the tide data available from NOAA stations in the area, including Sewell’s Point and the Yorktown USCG station. The use of similar vertical references and time intervals allows easy comparisons between these datasets. Data files are in comma separated value (CSV) text format and include columns for date, time, water level and battery voltage.

The station can collect and store data for over ten months in its current configuration. Battery life is predicted to be at least 70 days. Alternative power options may be possible which would extend this interval. Data is retrieved from the station using a Bluetooth RF connection. This connection is activated using a magnetic key to engage a reed switch inside a water-tight housing.

The data logger software is available for both Windows and Windows Mobile, so a laptop computer or a PDA can be used to collect the data. The software can also be used to re-program the datalogger in the field to change its operating parameters if desired.

Engineering

The system consists of Global Water, Inc. components, including WL-450 sensor (rated 0-15’ of water) (Photo 4), 25’ vented cable, and WL-16S datalogger (Photo 5). The vent inside the cable provides an atmospheric pressure signal to the back side of

Photo 4

Photo 5

the sensor diaphragm, eliminating a separate barometric pressure sensor to null out atmospheric pressure variations.

Communication between the datalogger and sensor is accomplished through an RS-485 current loop (4-20mA) circuit. The datalogger interface is a serial RS-232 connection using simple DTR signaling to initiate communications. A 4 pin DIN to 9 pin Dsub serial cable is provided with the datalogger.

Photo 6

Communication with the datalogger is through an AK-1500 Serial to Bluetooth module (Photo 6). All components are installed in locally fabricated housings and conduits as detailed below.

The sensor was calibrated as per the manufacturer’s procedure, using a 36” water column and the Global Logger II software provided.

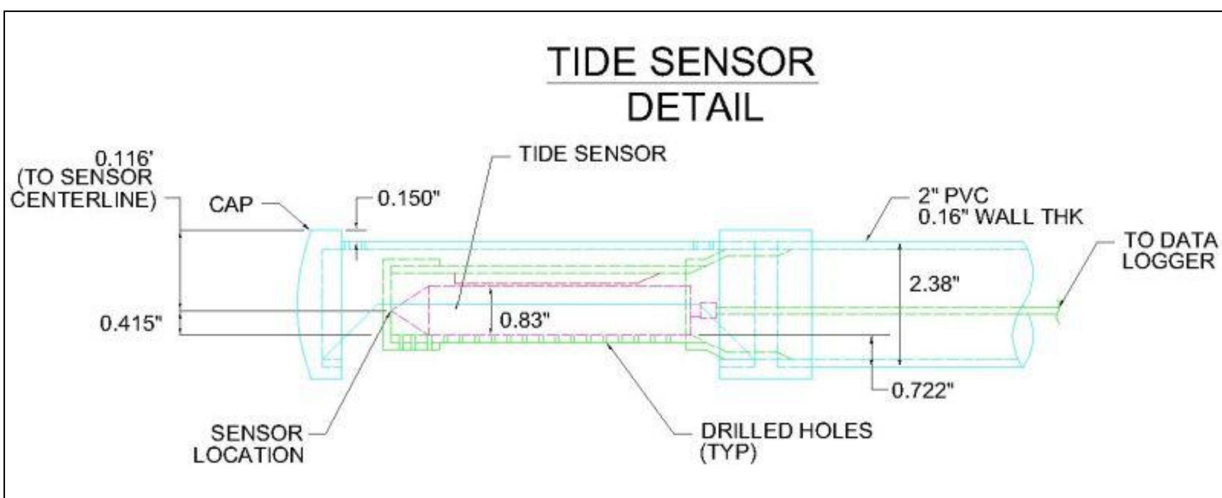


Figure 2

The sensor housing is shown in Figure 2. The sensor is installed in (nominal) 1” ID PVC conduit, perforated to allow water flow. A spacer at the top of the conduit forces the sensor to the bottom, preventing movement within the conduit.

The datalogger, interface adapter, Bluetooth module and associated cabling are installed in the dry housing shown in Figure 3. This housing consists of a 2” to 4” adapter, a 4” x 1’ long PVC pipe, and a pipe cap. The housing is mounted to the top of a 2" PVC conduit that runs down and then out into the water, terminating in the sensor housing. This conduit protects and supports the sensor and vented cable. The overall installation is diagrammed in Figure 7.

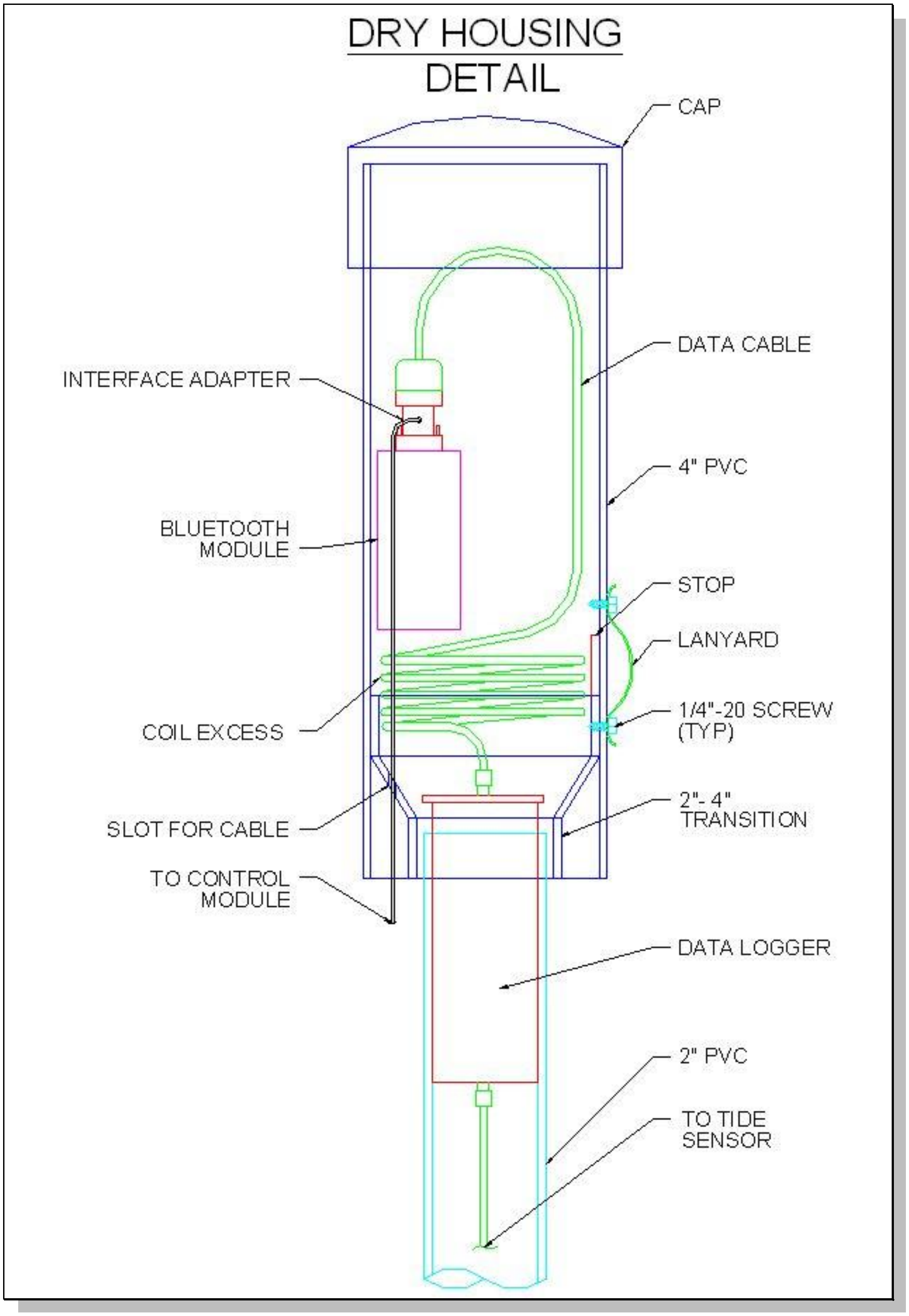


Figure 3

The Bluetooth module was modified, and a custom interface adapter was developed, to allow remote activation of the module. This was done in order to both conserve battery life in the Bluetooth module and to prevent unauthorized access to the data logger. The interface adapter, (Figure 4), is basically a break-out box that is installed between the datalogger and the Bluetooth module. It breaks out the DTR signal (used to activate the Bluetooth module) and the signal for the remote LED into a cable that connects to the control module.

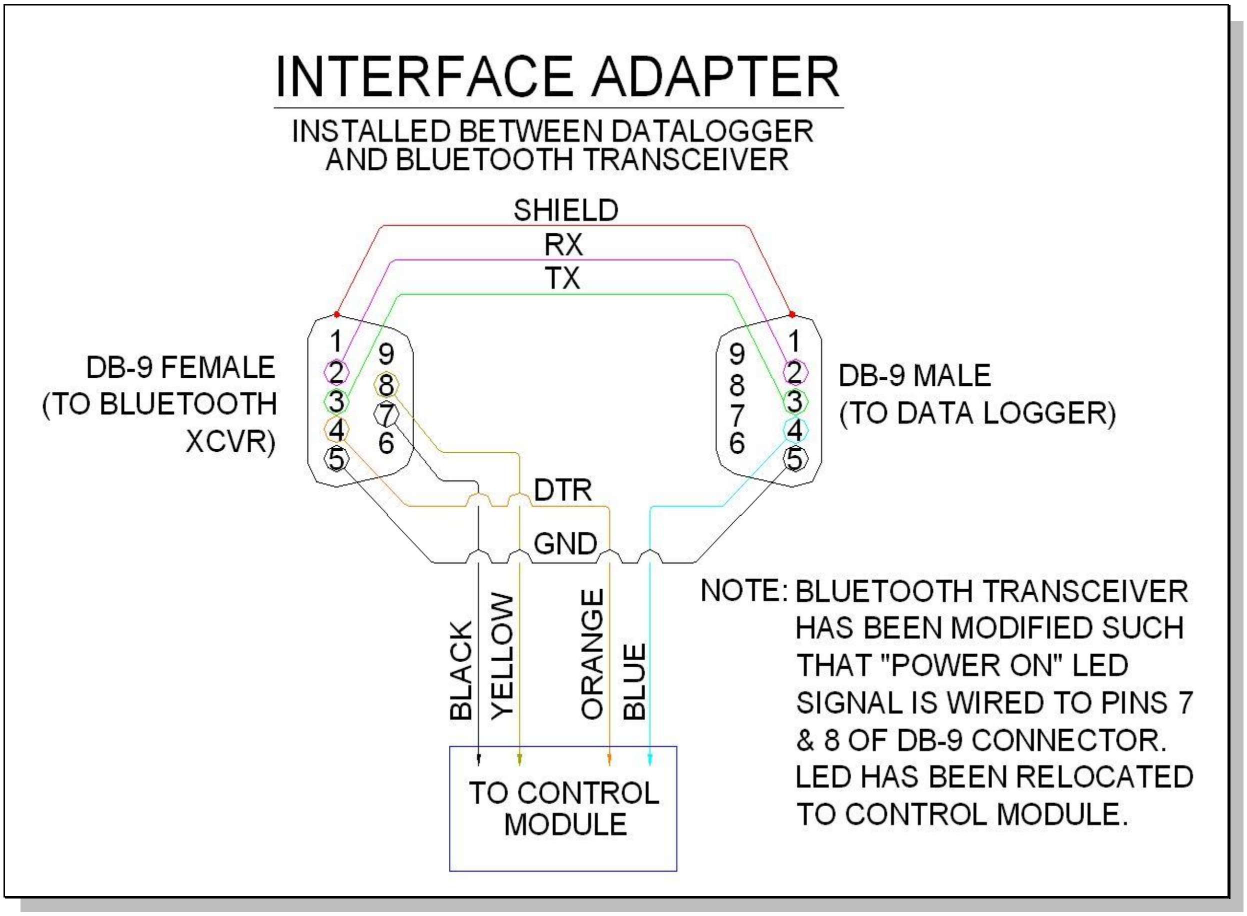


Figure 4

The remote activation switch and LED are installed in a water-tight control module. The switch is a reed type, normally open switch, controlled with an externally applied magnet. A suitable magnet has been incorporated into a key which snaps over the control module. (Figure 5) The red LED indicates when the Bluetooth module has been powered on. (Figure 6)

Photo 7 shows the magnetic key being snapped onto the control module.

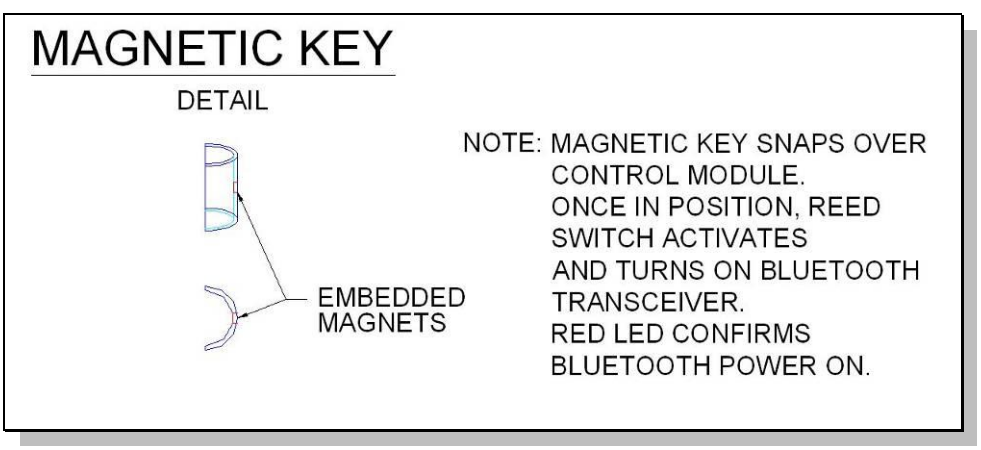


Figure 5

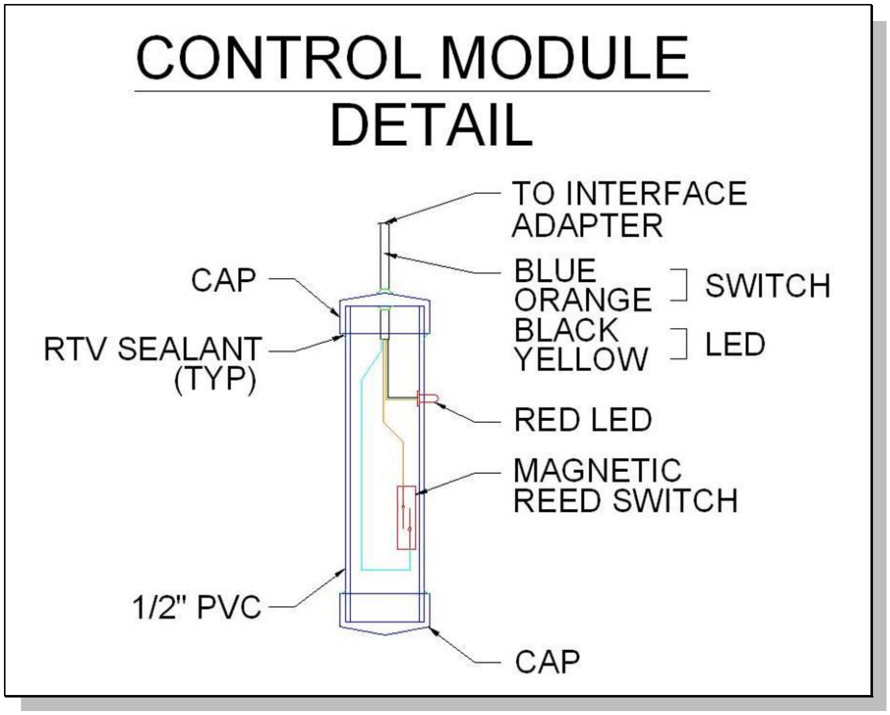
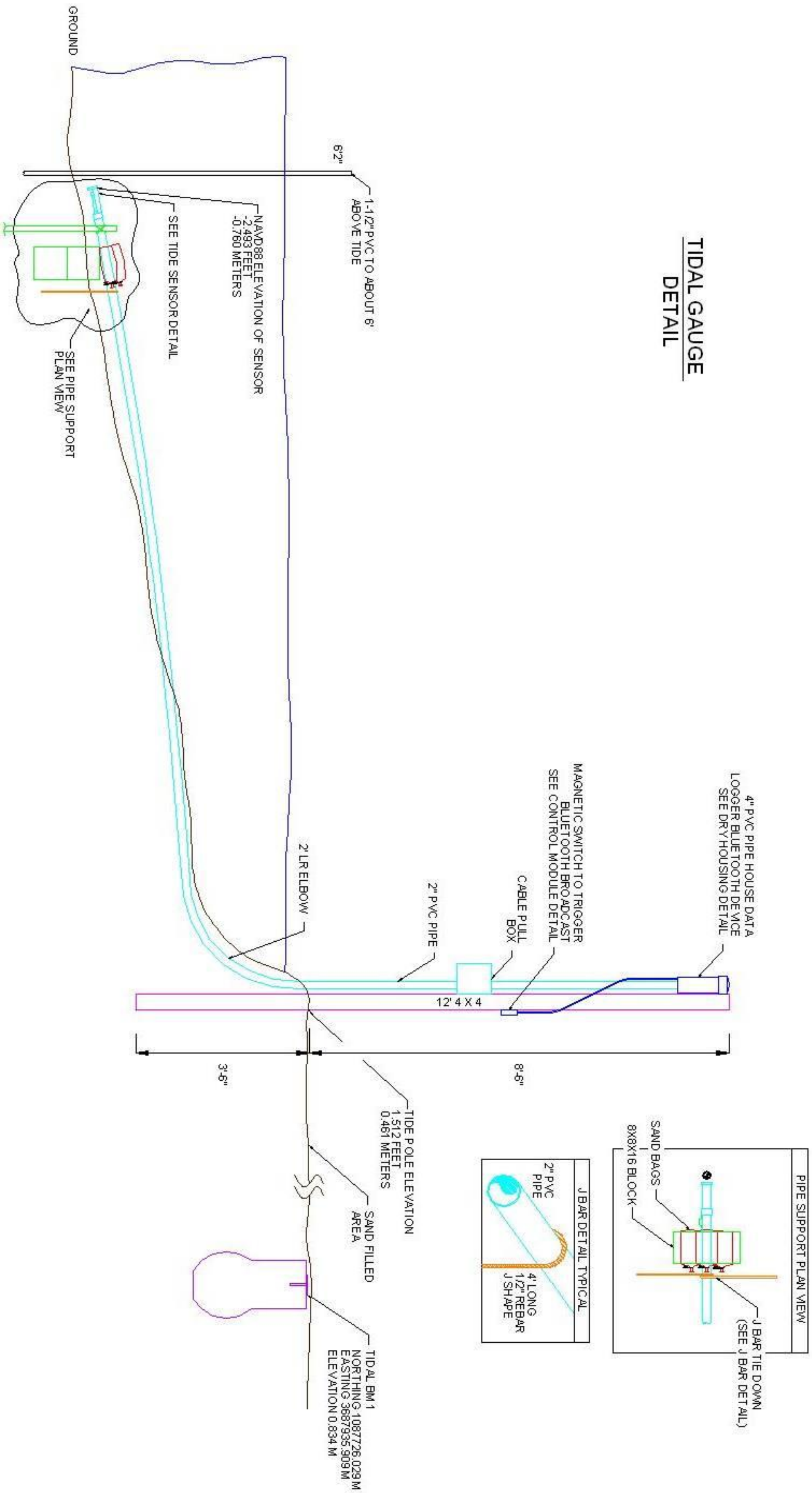


Figure 6

Photo 7



TIDAL GAUGE DETAIL
GROUND
6'2"
1-1/2" PVC TO ABOUT 6' ABOVE TIDE
NAVD88 ELEVATION OF SENSOR -2.493 FEET -0.760 METERS
SEE TIDE SENSOR DETAIL
SEE PIPE SUPPORT PLAN VIEW
2' LR ELBOW
2" PVC PIPE
CABLE PULL BOX
MAGNETIC SWITCH TO TRIGGER BLUETOOTH BROADCAST SEE CONTROL MODULE DETAIL
4" PVC PIPE HOUSE DATA LOGGER BLUETOOTH DEVICE SEE DRY HOUSING DETAIL
12' 4 X 4
3'-6"
8'-6"
TIDE POLE ELEVATION 1.512 FEET 0.461 METERS
SAND FILLED AREA
TIDAL BM 1 NORTHING 1087726.029M EASTING 3687935.909M ELEVATION 0.834 M
PIPE SUPPORT PLAN VIEW
SAND BAGS
8X8X16 BLOCK
J BAR TIE DOWN (SEE J BAR DETAIL)
J BAR DETAIL TYPICAL
2" PVC PIPE
4' LONG 1/2" REBAR J SHAPE

Figure 7

Surveying:

The sensor and visual standard were surveyed in reference to a local benchmark to obtain NAVD88 heights using a Trimble "DiNi" precision electronic/optical level. For this prototype, the benchmark was itself observed with GPS as an "Observed Control" point, in which 3 minutes of GPS observations are collected and averaged to obtain a reasonably accurate position.

This survey indicates a baseline NAVD88 height for the sensor of:

-2.493 feet (**-0.760 m**)

For a permanent station, a more precise leveling effort would be undertaken, using the DiNi instrument to perform a level loop back to a more precisely measured control monument.

The visual measurement standard was measured and marked prior to installation, anticipating that it could be placed such that its zero reference coincided with the centerline of the sensor. Unforeseen factors during installation prevented such alignment, therefore the reading as printed on the standard must be adjusted to correlate with sensor readings. To obtain water height above the sensor from visual readings on the standard, it is necessary to subtract 4.57" (0.116 m).

Survey details are shown in Figure 8

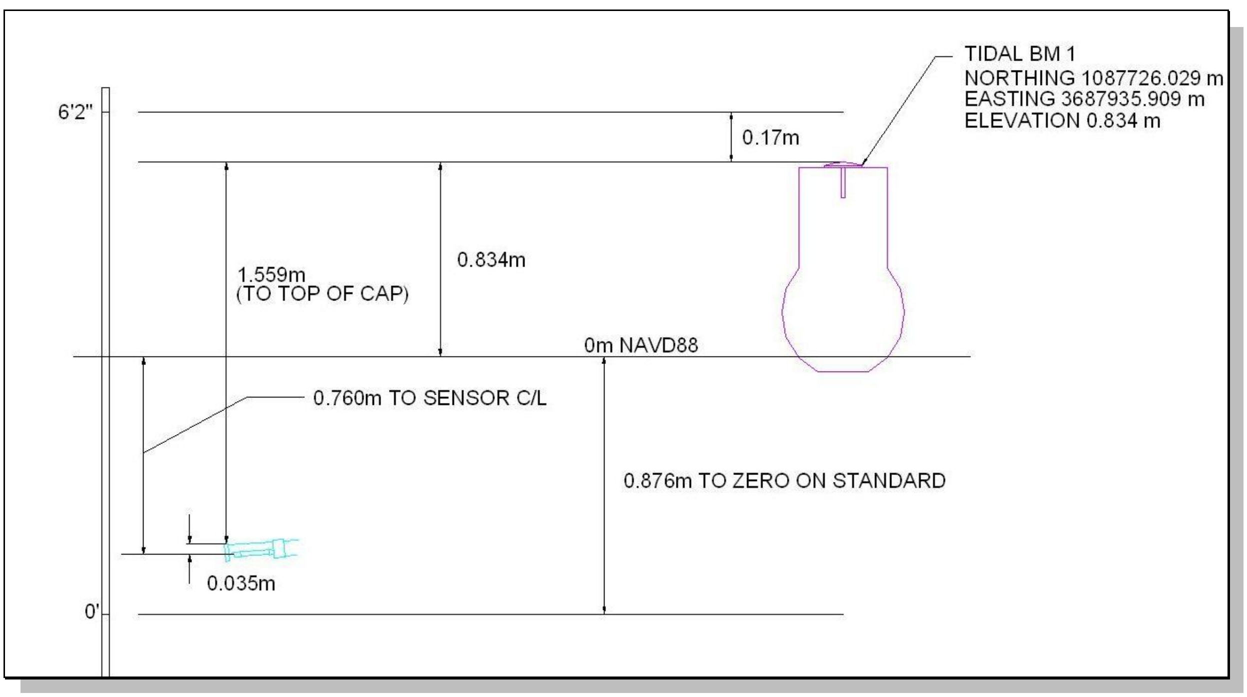


Figure 8

Specifications

WL16 Water Level Data Logger:

- Power: Two 9VDC Alkaline Batteries
    - Battery Life: Up to 1 year (depending on recording intervals)
- Resolution: 12 bit
- Temperature: -40° to +185°F (-40° to +85°C)
- Humidity: 0-95% non-condensing
- Memory: Non-volatile flash memory
    - Storage Capacity: 81,759 time and date stamped data points (including battery voltage)
- Sample Modes: High Speed (10 samples per second), Fixed Interval (Programmable from 1 sec to >1 year), Logarithmic, Exception
- Data Overwrite: Select memory wrap or unwrap (unwrap will stop logging data once memory is full)
- Clock: Synchronizes to the time and date of user's computer
- Clock Accuracy: 0.0025% or 1 minute in 1 month
- Clock Format: Month/Day/Year Hour/Minute/Second

Submersible Pressure Transducer:

- Sensor Element: Silicone Diaphragm, Wet/Wet Transducer
- Water Level Measuring Range: 0-15 ft
- Linearity and Hysteresis: ±0.1% FS
- Warm-Up Time: 3 seconds recommended
- Overpressure: Not to exceed 2 x full scale range
- Accuracy: ±0.2% of full scale, over 35°F to 70°F (1.37° to 21.1°C) range
- Compensation: Uses dynamic temperature compensation 30 to 70°F (-1.1 to 21.1°C). Automatic barometric pressure compensation

Error estimates

The minimum change in water level discernable by the system is 0.04” (1.11 mm) based on a 12 bit ADC and 15’ range. Variation between readings is governed by the Linearity and Hysteresis of the sensor; which for this system is ±0.18” (±4.57 mm). Therefore the error between readings is within ±0.22” (±5.68 mm).

The sensor is accurate to ±0.2% of full scale or ±0.36” (±9.10 mm) of water above the sensor. As shown above, the error associated with any given reading is ±0.22” (±5.68 mm). These together yield a combined absolute accuracy error of ±0.58” (±1.48 cm).

The one-sigma error in NAVD88 height of the sensor is < 1.18” (2.99 cm) based on the survey methods used for this prototype. Therefore the predicted error in absolute water level referenced to NAVD88 is within ±1.76” (±4.47 cm).

Cost breakdown

Commercial equipment from Global Water, Inc.:

• WL16S Water Level Logger with Standard 25' cable	$899
• WL16S-ACM Serial Water Level Logger Software Kit	$n/c
• Bluetooth External Adapter	$354
Local purchase/fab:	
• PVC conduit, fittings, lumber, fasteners, etc.	$125
• Interface adapter parts and cable (from local stock)	$n/c
Total	$1378

Schedule

The requirements for this prototype were presented to the GIS Team in early October. A parts list and preliminary design were developed and parts were ordered on October 19, 2010. The electronic equipment was received around November 10. Testing, calibration, and design and development of the interface and control module were completed by November 30. Fabrication and initial installation was completed by December 3. After problems with movement of the sensor were encountered with the installation, modifications were made and the installation was re-worked to make the sensor location more stable. Test operation of the system was finally initiated on December 6, 2010. Data was collected after one week, and the system was considered to be fully operational on December 13, 2010.

Operation

The GIS Team has dedicated a Dell Axim PDA running Windows Mobile OS 5, with the Global Logger II software installed and configured for Bluetooth access to the system. For this prototype, we will operate and maintain this station and provide the data to interested parties. We anticipate a data retrieval schedule of approximately every 2 months, to coincide with the battery replacement schedule. If and when a longer-lasting power option can be implemented, we may extend the data retrieval interval.

The data files will be stored on our server, which is backed up nightly. The data files will be stored in raw format. Corrections to MLLW, NAVD88, or other reference are the responsibility of the user. This allows us to better serve all customers equally. We will of course assist with conversions if needed.

Contact

Brad Ball (757) 864-7297 william.b.ball@nasa.gov

John Meyer (757) 864-6972 john.m.meyer@nasa.gov